Finish discussion

Revise intro

Then condense two results sections pars a bit. Add in results of raw curves.

Fix PCA

* Create sp abreviations
* Revise code
* Add sp names abrevs.
* Get rid of pca square traits
* Don’t use colour for two trait types.

Write remake script

Write dockerfile

## deconvolute

Write package tests and vignette

Submit package to ropensci for onboarding

Then write paper

Abstract

We use X method to calc Y.

To do X we do Y. we show how these traits are related, highlight functional tradeoff, we found that orthogonal variation.

The two axes conceptualised as the nutrient and carbon strategies

And these are indpedent facets of recalcitrance, and help explain the multivariate explanatiory traits related to decay.

We discuss XXX and conclude by X gaps.

‘coordination and trade-offs between biomass traits and other plant traits’.

Plant ecological function competition/resource use, stress, disturbance.

How do the two spectrums fit in?

Resistance to decay.

\*\* in intro refer to the other ways people tried to array species

Intro par

This work is the first attempt to use thermogravimetric analysis (TGA) in combination with mixture modelling to estimate the partitioning of carbon in a suite of wetland plants. We found that species allocate structural carbon into either predominantly cellulose-based or lignin-based carbon, and that variation in investment of structural carbon is orthogonal to variation in economic spectrum traits related to nutrient strategy.

Orthogonality results detailed – structural investment

Our results suggest two distinct axes of variation in multidimensional trait space (Fig.~\ref{Fig:PCA}). Economic spectrum traits aligned along one axis; Our results match those of the LES \citep{wright2004}, dividing species with nutrient-rich litter high in N and SLA from those with dense tissue high in DMC and C (Fig.~\ref{Fig:PCA}). Litter high in N and SLA suggests fast-growing, ‘nutrient acquisitive’, species, which allocate resources to relatively more labile photosynthetic tissue. Slow-growing, ‘nutrient conservative’, species investment more resources in dense structural tissue high in DMC and C \citep{aerts2000}. Biomass traits aligned on an orthogonal axis, dividing species by investment in inherently more labile carbons such as hemicelluloses and cellulose from complex lignin. The orthogonality of these two axes in our data suggests a decoupling of litter nutrient and carbon investment strategies. This may mean that while both axes’ traits correspond to a measure of recalcitrance, they are not substitutes for one another. Neither specific litter area nor litter dry matter content correlated strongly with any individual biomass trait (Fig.~\ref{Fig:pairplot}). This decoupling of nutrient and carbon strategies in litter suggests two somewhat independent pathways concerning litter decomposability. Empirical research confirms that traits related to both leaf economics and immobile carbon chemistry drive decay \citep{britson2016,cornelissen1999,cornelissen2001,cornwell2008,cornwell2014,freschet2012,freschet2012a,jackson2013}.

\*\*\* note papers where found independence/lack of coordination/orthogonality.

\*\*\* note those that found these traits did align.

**While \citet{dedeyn2008} claim** that plant traits involved in carbon and nutrient cycling are strongly coupled across functional groups and growth forms, this was not ubiquitous in our data. There was considerable variation within groupings for individual traits (Fig.~\ref{Fig:boxplot}), suggesting they are not very well conserved across growth form. Considering the diversity of species this is not altogether surprising. \textit{Cycnogeton procerum} is a monocot graminoid, but its fleshy aquatic tissue places it squarely among the forbs. There also lacked strong evolutionary patterns driving the traits (Fig.~\ref{phylogeny}), although additional work following up on evolution of recalcitrance in tissue would be valuable. Growth forms did, however, cluster in multi-variate trait space (Fig.~\ref{ Fig:PCA}). Forb species tended to have labile tissue both in terms of nutrient content and relative abundance of simple carbons. These species invest in short-lived nutrient-rich photosynthetic tissue. However not all photosynthetic tissue is nutrient-rich. Grasses, sedges, and rushes have small leaves, and the majority of their photosynthetic tissue must also provide structural support. Composed of a high contribution of relatively labile cellulose, we found that tissue of graminoid species was still nutrient conservative, clustering toward high DMC, and low SLA and N. Tree species contained higher amounts of lignin, reflecting investment in complex carbon, and also corresponded to a more nutrient conservative strategy. Expanding the carbon traits in our study to include the hemicelluloses and cellulose allowed us to draw these distinctions between labile and recalcitrant tissue in nutrient or carbon strategy that were not found elsewhere. For example, the whole-plant economic spectrum posited by \citet{freschet2012} found complementarity of economic spectrum traits with lignin.

An important caveat to these results is our focus on litter material. Empirical evidence suggests that there is considerable coordination in traits among plant organs \citep{jackson2013}, however it would be interesting to repeat the comparisons in this study using only leaves to compare with the leaf economic spectrum more overtly. In addition, it would be useful to examine biomass and nutrient economic traits in belowground tissue, as we know traits of above and below-ground tissue do not necessarily covary (ref), and belowground tissue impacts soil carbon significantly both through deposition of litter (ref) and soil priming (ref). This study focused on wetland species because of the relevance of plant litter decomposition dynamics to the rapid sequestration of soil carbon in wetland systems. Due both to acknowledged heterogeneity in LES across biomes \citep{wright2005}, and to the specific set of constraints on species' strategies in wetland systems affecting segregation along axes of variation \citep{moor2017}, it must be noted that these results may be particular to freshwater systems.

Tga results

The mixture model applied in this work, with proposed starting values and settings, produced DTG curves that match those presented in the literature for other biomass samples. The starting values reasonably predicted the DTG data for raw cellulose and lignin (reference result here). The mean \%wt estimates derived from integrating under these curves produced satisfactory mean estimates for the species. While few other studies measured the same species, our values are on the same range as those estimated for other species. XXX citations here. Compare species to species? I have a few comparison studies that would work.

While using the central tendency, in this case the mean, for estimation of these biomass attributes has produced reasonably confident estimates of the weights of biomass traits, estimated confidence intervals revealed that for some species, the shape of the DTG curve was less confidently resolved. Variation could be due to a DTG shape that is simply less identifiable – widths and positions of the curves’ starting values guided by literature and based upon underlying chemistry, but still could be sensitive to starting values or specification of parameter distribution. In addition to modelling sensitivity, variation in weight estimates could be due to biological or methodological variation. Considering the quick, and cost-effectiveness of the method it is worth further work to test alternative means to clarify and standardise the methodology to other methods of biomass estimation.

\section{Conclusions}

We found that TGA coupled with modelling approaches is a rapid, low-cost assessment method that can be used to estimate partitioning of litter carbon. The method outlined in this paper, in combination with publicly accessible mixture model code, produce a transparent, reproducible, and relatively affordable method to increase exploration of biomass traits of species. We found that structural allocation to complex or simple carbon sforms is not necessarily coupled to a species’ nutrient investment strategy. These multivariate carbon and nutrient trait axes may also reflect two alternative mechanistic pathways to understanding litter recalcitrance. These orthogonal axes suggest that by measuring carbon biomass traits, we are adding additional dimensions to understanding our species. Inclusion of these biomass traits in future trait-based modelling, particularly regarding decay, will be important. It remains to be seen how well this pattern holds up in plants from other systems and in other tissue types.

We found that economic spectrum traits in general may not be sufficient to approximate species’ carbon investment strategies in a multivariate context.

Nutrient availability in tissue as well as the complexity of biomass carbon affect litter recalcitrance.